

Waitaha Hydro Power Review of Intake Engineering and Fish Passage

Waitaha Hydro Expert Consenting Panel



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Waitaha Hydro Power Review of Intake Engineering and Fish Passage

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Report reference: 2501-A

Date: 26 January 2026

Copies to: Waitaha Hydro Expert Consenting Panel
(Electronic copy)

Issue	Details	Date
1.0	2501-A Waitaha Hydro Review of Intake Engineering and fish passage	23 January 2026
2.0	2501-A Waitaha Hydro Review of Intake Engineering and fish passage	26 January 2026

Contents

1.0	Introduction	1
1.1	Qualifications and Experience	1
1.2	Scope.....	2
1.3	Reports and information reviewed.....	2
2.0	Gaps in Information Provided.....	3
3.0	Summary of Key Issues from my review	4
4.0	Fish Screening and Fish Passage.....	6
5.0	Upstream Fish Passage	6
5.1	Power Station Tailrace Flow	6
5.2	River section between intake and power station.....	8
5.3	River Intake Structure	8
5.4	Risks of enabling other fish species upstream of Morgan Gorge.....	9
6.0	Downstream Fish Passage	11
6.1	Hydro power intake	11
6.2	Fish Screening	12
6.3	Environmental flow release.....	12
6.4	Sluice flow.....	13
6.5	Overflow weir and main weir	13
6.6	Discussion of approach to River Intake Design	13
7.0	Engineering Issues	14
7.1	Original Questions from Panel outlined in scope.....	14
7.2	Hydraulic analysis and design of the river intake.....	17
8.0	Conclusions.....	17
9.0	Limitation.....	19

1.0 Introduction

I have been engaged by the Environment Protection Authority to provide technical advice to the Waitaha Hydro Power Expert Consenting Panel. This advice relates to engineering issues associated with the proposed hydro power scheme and issues related to upstream and downstream movement of fish. I have been asked to provide a summary of my qualifications and experience and in this section, I also present the scope of my technical review and advice.

1.1 Qualifications and Experience

My qualifications are a Bachelor of Engineering (hon) in civil engineering from University of Auckland 1997 and a Bachelor of Science (Biological sciences) from University of Otago 1990. I am a Chartered Professional Engineer CPEng (civil) and Fellow of IPENZ (FIPENZ). Prior to working independently since November 2025, I was the Technical Leader and Practice Lead in Water Resources at Stantec for 2.5 years and previously was a Project Director at Riley from 2010 to 2023. I have over 28 years' experience in the assessment, design, and development of water infrastructure, particularly in hydropower, irrigation, river engineering and freshwater fish protection. My expertise includes concept development, consent applications, design, construction, and operation. I also have experience in hydraulic modelling, flood assessments, river engineering, and hydrology. I have 18 years' experience in fish passage and fish screen facilities at river intakes and am a leading engineer in New Zealand in this field.

I was a member of the Canterbury-based Fish Screen Working Group for several years providing engineering advice and supporting the development of assessment tools and design guidelines for fish screen facilities. I was a co-author of the NIWA Fish Screen Facility Guidelines (2023).

Over the last 18 years, I have successfully combined technical engineering skills related to hydraulics, river engineering, and structures with an understanding of aquatic ecology, particularly freshwater fish. By understanding freshwater fish needs and behaviour around structures, I have integrated ecological knowledge with hydraulic design to assess and develop solutions that improve fish protection during both upstream and downstream movement. I have attended international conferences related to fish and fish passage, presented at several conferences on freshwater fish protection, and been on study tours to the USA and Australia focused on fish screen facilities.

I have worked on over 50 fish screen sites in New Zealand and many projects involving fish passage in New Zealand. I have also worked on fish related projects in Australia, USA, Canada, and the UK. In Canterbury, my work includes the largest Irrigation Intakes and fish screen facilities, which include: Rangitata Diversion Race, Amuri Irrigation, Lower Waitaki Irrigation, North Otago Irrigation, Morven Glenavy Ikawai Irrigation, Opuha Water, Rangitata South, and Barrhill Chertsey Irrigation.

I have worked on over 100 river intakes for hydro power, irrigation and water supply mostly in NZ but also in Australia, USA, Canada, and the UK. I have previously undertaken work for Trustpower on several West Coast Hydro power schemes and other alpine river intakes in New Zealand.

1.2 Scope

I have been contracted to provide hydraulic engineering and fish screening and fish passage advice to the Waitaha Hydro Expert Consenting Panel. The scope has included reading the relevant application documents, conditions and other related information including any relevant comments from invited parties and providing advice to the panel on the following:

- Whether the intake structure is going to pass residual flow reliably
- Whether the intake structure is going to pass sediment reliably
- Whether the desander is likely to work as intended
- The overall robustness of the analysis and conclusions, any gaps or areas where clarification or further information would assist, and the appropriateness of the conditions to address hydraulic engineering matters.
- An assessment and advice relating to fish passage upstream and downstream of the structure and protection of fish.

1.3 Reports and information reviewed

The following is a list of the reports and information that I have reviewed. I have also read the report from Jon Tunnicliffe and had several meetings with some or all the panel to discuss the project and issues from my review.

Reports

Waitaha-Hydro-project-substantive-application-documents (SA/AEE)

Appendix-3-project-overview-report-part1/part 2

Appendix-9-feedback-from-DOC

Appendix-17-geology-and-geotechnical-report (for background context only)

Appendix-18-hydrology-report

Appendix-19-sediment-report

Appendix-25-freshwater-ecology-report

Appendix-26-IFIM-report

Appendix-31-downstream-flow-modelling-report

Appendix-42-conceptual-scheme-design-drawings

Appendix-44-preliminary-instream-structure-drawings

Management Plans

Appendix-33-construction-and-environmental-management-plan

Appendix-34-erosion-and-sediment-control-plan

Appendix-39-freshwater-ecology-management-plan

Proposed conditions

Appendix-45-proposed-conditions-resource-consent

Appendix-46-proposed-conditions-DOC-concessions

Appendix-48-proposed-conditions-complex-freshwater-fishery-activities

Appendix-49-fish-facility-information-for-complex-freshwater-fishery-activities

Responses to RFIs from the panel

Attachement A 260109 Memo - Hydraulic design and operating conditions

Attachement B 260109 Memo - Residual Flow (abnormal operating) (002)

Westpower Memorandum 6 responding to RFI 2, 16 January 2026

The material presented is within my area of expertise unless I state otherwise. I have considered all material facts known to me, and I have indicated the impact of any information gaps on my review and conclusions.

2.0 Gaps in Information Provided

The following was the initial assessment of information provided and the gaps in information that impact on my review:

- Details of the hydraulic analysis and for the structures proposed at the river intake. The hydraulic design would typically include analysis of flows, water levels, velocities and for a river intake include hydraulic modelling. Examples of hydraulic analysis is included in "Appendix-31-downstream-flow-modelling-report". There are no details about the flow of water over and through associated structures or the downstream conveyance (Main weir, overflow weir, sluice, environmental flow, intake). This would be expected to include hydraulic analysis for design conditions but also for different operating conditions regarding river flows and water levels and different generation flow conditions.
- There are limited details of sediment issues regarding deposition and mobilisation and issues of the effects of a weir constructed across the river. The processes of deposition including location, material size, quantities and how that relates to the operation of the intake are not presented.
- There are no drawings of the downstream parts of the main weir, overflow weir, sluice, and environmental flow. There are comments that much of this sort of detail will be developed in detailed design.

- There is no indication of the development of the intake concept or alternative intake types that were assessed and why this option is considered the best solution.
- There is no evidence of any development of engineering at the structures to provide for effective upstream fish passage and safe downstream passage.
- There are several issues of how fish will be attracted to or away from parts of the system which have been indicated will be addressed in detailed design but in some cases, these do not seem possible based on hydraulics and where the flows are directed.

Following the RFI from the panel some information was sent including *Attachment A 260109 Memo - Hydraulic design and operating conditions*. This provides a brief summary of the hydraulic design (2 pages of information). As there a number of other detailed reports provided, this would suggest there is not a detailed report specifically on the hydraulics available. This memo provides some further information on the hydraulics of the proposed scheme, but it is very limited in detail.

3.0 Summary of Key Issues from my review

From an engineering perspective the biggest risks associated with most intakes, and this applies to the Waitaha intake, is the flood effects and closely linked issues of sediment and debris management and geomorphological effects. For this river catchment the sediment is likely to be the most significant concern, but it is important to not underestimate the issues of debris especially as it is proposed to have a debris/rock screen with 30mm to 40mm spacing.

The design presented does not appear to have been through a very thorough and detailed assessment of the requirements for management of sediment and especially coarse sediment (gravel, cobbles and boulders) or the effects of constructing a weir across this river in this location. I would have expected in developing concepts there would have been included a detailed review of other intakes on West Coast, lessons learnt, consideration of design features that are required to manage sediment and debris and what the alternatives to the presented intake design is available. The design has focussed on a system to manage flows and sand but appears very limited in approach to coarser sediment. Based on assessment by Jon Tunicliffe and my experience in similar river environments the main approach will require physically removing coarse sediment and debris that arrives at the intake. The effects of the deposition of this material on the hydraulics before, during and after its deposition has not been presented. Sluicing systems generally work well for sands and silts but they are limited to how far their impacts will extend.

The design for solutions to the very significant issues of creating barriers to upstream fish passage for kōaro at the tailrace and the intake weir have been pushed to later in detailed design with no clear effective solutions being presented. There is also no evidence of consideration of ways to reduce risks to downstream moving fish at the weir infrastructure as much of what is proposed all appear to present risks of harm to fish.

Questions from the concept that is presented and which I have not seen evidence of it being answered:

- Is a weir structure perpendicular to the flow blocking all flow in the river the best Intake type for this location? That is a very traditional solution and there are many issues an option like this creates in a steep and very active river system. These include:
 - The weir is a significant barrier to sediment transport downstream, at least initially until the area's upstream fills with sediment or flows are large enough to carry this sediment over the structure.
 - The weir creates a backwater effect upstream which effects the natural river habitat through permanently flooding areas currently that only flood in high flow conditions.
 - The area upstream is likely over time to fill with sediment and regrade the stream creating bed level changes far more significant than what occurs through natural stream processes
 - The weir is a significant barrier to upstream fish passage and requires designing a system to attract and enable fish to pass upstream safely. There has been very limited success in fish passage for any structures with significant water level differences as this will have which often relates to the complexity of hydraulics and ability to attract fish to a fish pass.
 - The weir creates a sudden change in water velocity as the releases from the weir will have up to 7m head of energy to dissipate creating greater risk of harm to downstream moving fish.
- Does the weir need to be 7m high as greater height has implications for sediment but also energy to dissipate and environmental effects including upstream fish passage difficulties?
- Will the intake be overcome by coarse sediment gravel/cobbles/boulders? Is there a different type of design that would allow for the continued movement of this coarser sediment downstream. There are alternative designs of West Coast intakes that do that such as at Amethyst and intakes for some of the Manawa hydro schemes. Those types of intakes may not necessarily be suitable for Waitaha but what they highlight is an approach to maintain the movement downstream of very large quantities of sediment and especially coarser sized sediment.

- Has enough effort been put into the development of the intake given it is fundamentally the biggest risk for this project? There are a lot of lessons to be learnt from other intakes that have been constructed along the West Coast and even up into Marlborough which have similar challenging river environments. The design for the management of coarse sediment and debris appears to be very limited.
- Will it be possible with the designs presented to avoid creating significant barriers to upstream fish passage for kōaro and to be able to provide suitable protection to downstream moving fish and especially kōaro larvae?

4.0 Fish Screening and Fish Passage

To consider issues related to fish screening and fish passage first there needs to be the wider consideration of the movement of fish upstream and downstream over the entire river space impacted by the proposed scheme.

From a review of the Ecology Report (Appendix-25-freshwater-ecology-report) it indicates that although there are several fish species downstream of Morgan Gorge, the only fish species found upstream is kōaro which also is indicated as the most abundant species found in the Waitaha River. kōaro are very good climbers but not very strong swimmers. It is a little surprising that there is no evidence of eels upstream, but they have reported a variety of different methods used to survey for fish in the catchment.

It is believed that a key reason for the significant reduction in number of kōaro across NZ and why it is Classified as “At Risk – Declining” is due to introduced species and especially Trout and Smelt. The surveys show that above Morgan Gorge there are only kōaro so this makes protection of them even more important given there is no risk of predation from fish in that area of the river for them. The Freshwater Ecology report highlights the significance of this habitat for kōaro upstream of Morgan Gorge on a regional basis and importance of maintaining that.

Key points of consideration for safe and effective passage of fish within the system are where there are changes in flows and effects of structures. The following breaks this down into a section on upstream fish passage within the extents of the scheme and downstream passage at the weir structure.

5.0 Upstream Fish Passage

There are three main locations of concern for fish passage which includes the tailrace, the river section between intake and tailrace and the intake.

5.1 Power Station Tailrace Flow

The Freshwater Ecology Report includes section 3.15 Fish attraction to the tailrace (a) & (b). In this section it states:

(a) Fish Species such as kōaro, torrentfish, brown trout, and longfin eel are likely to be attracted to the tailrace discharging into the Waitaha River. Specifically, juvenile kōaro migrating upstream along the river's edge may be drawn into the tailrace, potentially reducing their numbers moving upstream.

(b) The design will need to incorporate features or measures that will help to discourage or limit fish access into the tailrace and/or facilitate the upstream movement of fish that may be otherwise attracted to the tail race; with this being facilitated by the inclusion of a suitably qualified and experienced freshwater ecologist during the detailed design phase. Checking the structure after any significant bed-moving flood event will also be useful as it can identify if any remediation works are needed to maintain such fish passage features.

It is likely that kōaro will be migrating along the river's edge as stated above given they are relatively weak swimmers. It is unlikely kōaro on the river right (tailrace side) would be able to get past the tailrace unless it was not operating or operating at very low flow conditions.

The hydrology report indicates the residual flow at the weir is only $3.5\text{m}^3/\text{s}$ and the tailrace flow will be up to $23\text{m}^3/\text{s}$. The 10th percentile flow is $9.1\text{m}^3/\text{s}$ so that means the tailrace flows will be $5.5\text{m}^3/\text{s}$ at the 10th percentile increasing to $23\text{m}^3/\text{s}$ at the 66th percentile. The river left side is not impacted by the tailrace so that will enable migration upstream but without any specific details at best we can assume the tailrace risk will impact on at least 50% of the kōaro given there is some influence on flows and velocities well out into the river from the tailrace. (There are some tributary flows between the intake and tailrace that have been suggested are an average of $0.7\text{m}^3/\text{s}$ but at 10th percentile much lower than that which I have not accounted for but are not significant)

A freshwater ecologist will be able to provide some guidance on this issue but importantly will need a suitably experienced and qualified engineer with specific fish passage related skills who is able to develop potential solutions as this will be technically challenging. The concern is whether there are feasible design measures able to discourage or limit fish access into the tailrace? Based on the hydrology and the geometry of a power station tailrace it is unclear how this issue can be overcome and no suggested solutions have been presented. This poses a significant risk of approximately 50% of the kōaro not getting upstream and without any indication of how this will be achieved there is a concern that this will not be resolved in detailed design.

The other issue with the tailrace is that it is indicated that several species will be attracted to the tailrace and including brown trout and eels. This then is attracting fish into what is a dead-end for upstream fish passage and given the listed species that will be attracted include brown trout and eels this increases the risks of predation for small fish such as the kōaro from these fish all being attracted into the same space.

5.2 River section between intake and power station

The Aquatic Ecology report and associated IFIM modelling have shown there is not expected to be any significant changes regarding upstream passage through this section for kōaro and more likely there are positives regarding reduced flows and velocity.

The reduced flow may make this section of the river more accessible for other species with the most likely being eel. It may also increase the risk of trout making it further upstream but that is less likely. Therefore, in addition to the standard IFIM studies this section of the river needs to be considered in terms of what changes in fish passage may occur for a flow of 3.5m³/s. This is considered in more detail in Section 5.4.

5.3 River Intake Structure

The Ecology report Section 3.16 Fish Passage at Weir Intake Structure includes consideration of upstream passage at the weir including:

(c) Detailed design of the kōaro passage structure will need to consider the positioning of these other discharges to ensure kōaro are attracted to the kōaro passage structure rather than the residual flow or sluice gate, further highlighting the need for input from a qualified freshwater ecologist during the design phase.

A fish passage structure will have a very low flow and potentially only several litres/s whereas the environmental flow is 3.5m³/s and continuous (66% of the time it is the only flow downstream of the weir) so in low flow to moderate flow conditions kōaro will be attracted to this location. The environmental flow release is on the river right of the structure so seems obvious that the proposed location for the passage structure on the river left will not be suitable to attract kōaro given the associated flow at the structure is likely to be in the order of 1% of the flow or less.

The sluice is less relevant as it is only infrequently operated but there is a need to still consider any potential negative effects of its location. The other downstream flow is the spilling at the overflow and main weir which will also occur for 34% of the time. It is proposed to have a fish pass that has a lower level than the spill weir to release water and ideally the fish pass should be designed to be effective for as wide a range of flows as possible. The best practice is to base that upon the flow duration curve and design for fish passage to be possible between the 95% exceedance and somewhere in the range of 80% to 90% exceedance. Figure 1 shows the flow duration curve for the Waitaha River at the intake so fish passage should be designed for minimum flows of 3.5m³/s and up to at least 40m³/s. The fish pass will therefore also need to still be effective for initial flows spilling over the weir. In addition to the downstream part of a fish pass attracting kōaro the upstream conditions need to be considered. Designing a fish pass with variable upstream water levels is challenging and given all the other infrastructure and places where water is directed downstream (weirs, sluice, environmental flow and intake) the fishway needs to be located to direct kōaro to a safe place upstream so they can continue migrating upstream of the intake and not be entrained into any of those downstream flows.

It is important to note that most fish passes at weirs and dams in NZ do not work effectively. The key to success is the combination of both a suitably qualified and experienced ecologist with a suitably experienced and qualified engineer who can find a solution that works for all the components of the intake. It requires integration of a fish pass with all the other processes and functions at the intake.

The concern with this site is that the weir is in the order of 4 to 7m high on the downstream side and has a lot of infrastructure across the entire width of the river that directs flows downstream at different times. So, finding a solution that starts from where the environmental flows are released and other spill flows, and directing to a suitable safe location upstream, accounting for the changes in upstream water level and given that a pass for a kōaro requires very limited flows in all conditions, appears to be a very significant challenge. What has been proposed in the application is a pass on the river left which is not a suitable solution when combined with where the environmental flows are located and will need to consider risks associated with the spill flows. It is also unclear how flows for a fish pass will be controlled for different upstream water levels as the flows will need to be maintained at a similar level for a variation in upstream water levels including when flows are being spilled over the weir.

The related concern is that generally these structures are designed by engineers who have expertise and experience with the physical properties for water but may not have a detailed understanding or knowledge of the changes to design processes to better account for fish passage and fish protection. This often leads to the fish passage and protection being considered separately to and often after the main design of structures so becomes a retrofit. This often leads to solutions that are not good for fish as the design based on physical properties of water have set significant constraints to fish passage design.

5.4 Risks of enabling other fish species upstream of Morgan Gorge

The operation of the scheme results in a significant change to the flows downstream of the intake weir to the tailrace. The maximum flow for 66% of the time will be in the order of 3.5m³/s with a little more from minor tributaries for part of that river section. Figure 1 shows the Flow Duration Curve at the Intake from the Hydrology Report. The flows will be significantly less in that section for 90% of the time. But more importantly for at least 66% of the time the flows will be lower than the lowest natural flows and well below the MALF.

The natural barrier that Morgan Gorge is to all upstream fish passage other than for kōaro could therefore change with this very different flow regime. This is most likely for eels as they are good climbers but may also be true for strong swimming fish such as trout as the low flow conditions may create a pathway for these fish to get up through the gorge.

The proposed intake structure does pose a barrier to these fish getting upstream into Kiwi Flats. However, it is very likely that a fish pass that is effective in enabling kōaro to get upstream will also be suitable for eels. Designing a fish pass for kōaro and not eel would be very challenging.

Trout would need to swim through the environmental flow release but that appears unlikely given the velocities I have calculated through that structure but if trout are waiting immediately downstream of the intake when a higher flow event arrives and drowns out the intake (information from applicant indicated this occurs at 150m³/s) then it may then be possible for trout to move upstream when that occurs.

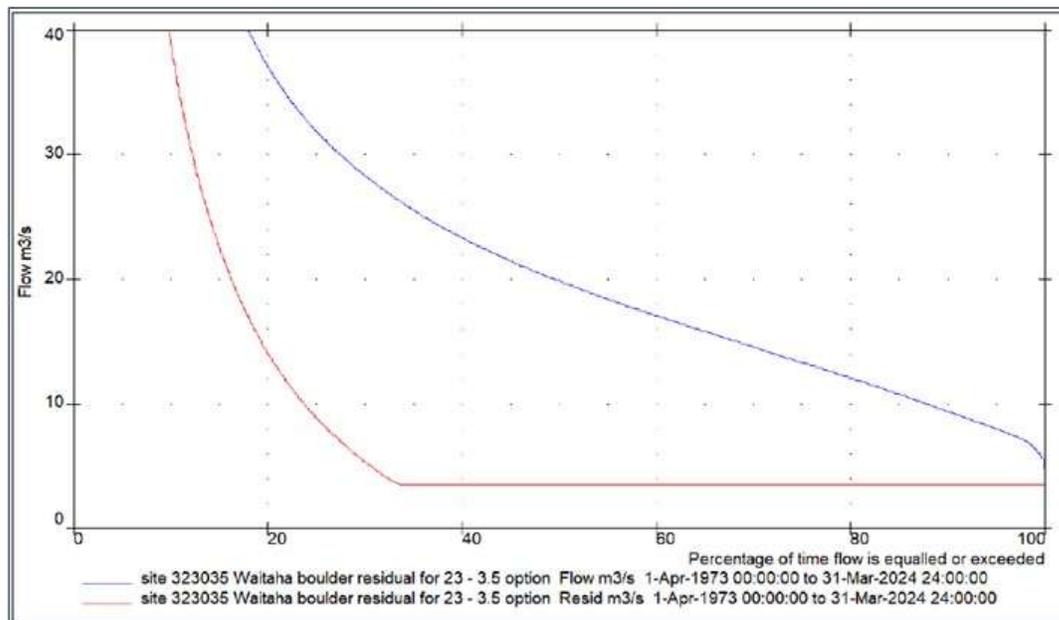


Figure 1 Percentage of time residual flow occurs for a take ranging from 0 to 23 m³/s (using all months).

Without any detailed assessment and based on limited information the risks of eels getting upstream would seem high but trout much lower. It is not clear how eel could be excluded in this scenario and therefore introduces a potential effect on the kōaro upstream given currently they are the only fish present. The surveys have shown that kōaro are present in more limited numbers upstream due to natural barriers. Any introduction of other fish species such as eel may be a concern given the already limited numbers of kōaro.

6.0 Downstream Fish Passage

The three main mechanisms for harm to fish are through **physical strike**, **barometric pressure changes** and **shear stress**. Although in general smaller fish are less likely to be affected by physical strike than larger fish, they are generally more susceptible to barometric changes with larvae being the most sensitive to barometric pressure changes: (decompression). Studies in Australia of very low head undershot gates of only a few metres found larvae can be affected even at sudden barometric pressure changes with only a few metres head. They have found decompression that reduces pressure to less than 40% of what the fish is acclimatised to within the system before that sudden change occurs results in injury. This means hydro power systems pose a significant risk of harm to larvae.

Fish can cope with very large increases in pressure; it is the sudden decreases in pressure which are the greater risk for harm. The risks of where sudden decompression will occur is within the turbines but also through gates especially if they are undershot/slucice type gates which is type proposed for the intake gate, sluice gate and environmental flow gate.

6.1 Hydro power intake

In 3.14 (a) of the Freshwater Ecology report it states kōaro are likely to survive passage through low-head turbines. This may be true for low head schemes, but this is not a low-head scheme as it is over 100m of head so would be considered as a moderate to high head power station.

Mortality rates for fish through hydro schemes based on international studies have found average instantaneous mortality is approx. 22% but varies from 0-100% based on turbine type, head, turbine design, fish species and life stage of fish. This is based on a recent international review¹ in a paper from a university in Germany of almost 100 different physical studies of live fish with over 275,000 fish and 90 different species. This confirmed that the outcome regarding harm to fish is very site dependent and using a study from somewhere else is only relevant if there are a lot of similarities between sites regarding head, flow, turbine type and species of fish. A standard Francis turbine with 100m head would be expected to be worse than the average of these studies as a number included low head schemes with more fish friendly turbines such as a Kaplan.

¹ Radinger, J., Van Treeeck, R., Wolter, C (2021). Evident but context-dependent mortality of fish passing hydroelectric turbines. Leibniz Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany.

6.2 Fish Screening

The design has included a screen at the intake, and while I have not sighted any specific details, I understand it is a coarse screen proposed and for debris. Therefore, this coarse screen will be designed to avoid any reasonable size debris entering the intake and is not a fish screen. The velocity at the intake will be in the order of 0.4m/s based on the total area of the intake opening contributing to the flow. It appears that the screen may only be half of that opening and therefore the velocities may be approximately 0.8ms at the screen. These velocities are significantly above what would be required to screen for juvenile kōaro. It is likely velocities less than 0.12m/s would be required to provide for the ability of these fish to swim upstream and away from the intake.

Very few hydro power schemes have any form of fish screening and for a river like the Waitaha with extremely high sediment loads and high risks from flood events carrying large debris and rocks it would not be feasible to include a fish screen that would be compliant with best practice for fish screening at an intake. Screening larvae is even more difficult and less feasible. Therefore, to address the risk of harm to kōaro from the hydro power intake and hydro infrastructure; other approaches would need to be considered and that could include consideration of the turbine design to reduce that risk. The Ecology report states the design will include hydraulic features to manage the approach and sweeping velocity to keep fish and debris out of the tunnel. There is no information of what those features are, and the drawings and summary of operation do not provide anything that would achieve that. The presented information shows that for up to 66% of the time all of the flow will be directed into the intake and environmental flow which is at the same location and there is even a comment that the environmental flow may be placed within the intake. In that scenario all of the flow is directed into the intake so does not appear possible for any hydraulic features to keep fish and all debris out of the tunnel.

6.3 Environmental flow release

Studies in Australia of very low head undershot gates of only a few metres found larvae can be affected even at sudden barometric pressure changes with only a few metres head. They have found decompression that reduces pressure to less than 40% of what the fish is acclimatised to results in injury. Although water levels are not specified for operation based on weir level and the position of the environmental release; there will be in the order of at least 7m head which downstream from the environmental flow gate which will decrease to 0m head so there is the potential to exceed the 40% threshold found in studies which carries a risk of barotrauma harm to fish. The recent information on the summary of hydraulics has indicated the environmental flow release will have an opening of 1m by 1m and that when fully open the capacity would be up to 10m³/s which suggests the gate will be mostly closed. This suggests the velocities may be up to or more than 10m/s. The combination of a deep opening, mostly closed gate opening and very high velocities all introduce significant risks of harm to any fish. There are other gate options for flow release that have much lower risk of harm to fish.

Although covered elsewhere the location of the environmental flow which is only downstream flow at the structure for up to 66% of the time and is dislocated from a proposed fish pass on the other side of the river, is also of concern.

6.4 Sluice flow

Many of the same issues with the environmental flow apply to the sluice which has a higher flow but does not operate very often. Given the sluice flow will only occur for very small percentages of time and therefore overall, a much smaller percentage of flow passed; the effects are much lower than the constant release from the environmental flow. The factors required for a sluice to work are also difficult to modify.

6.5 Overflow weir and main weir

The overflow weirs will operate 34% of the time. These generally will not have risks associated with barotrauma but will have risks from strike and/or shear forces in the water being a risk of harm to fish it is the downstream design of these structures that will affect that. Of concern in the summary of hydraulic information sent through is mention of steps or other mechanisms for energy dissipation at the weir. If the design of energy dissipation considers only the physical properties of water this will almost certainly result in risk of harm to fish. The design for any energy dissipation structures at the intake needs to include an integration with design for reducing the risk of harm to fish.

The Freshwater Aquatic report includes Section 4.16 Fish passage at weir intake structure

(a) Detailed design of the kōaro passage structure and relevant Headworks infrastructure (i.e weir, sluice gate, intake) should involve input from a suitably qualified and experienced freshwater ecologist, as well as oversight during construction of the kōaro fish passage structure, to ensure that 3.16 is able to be met.

As commented previously it is important to have this input from ecologists, but it is the engineers that will need to develop the designs of the structures, and it is important that they have the experience and skills in the design for safe passage of fish or the oversight by an engineer that does.

6.6 Discussion of approach to River Intake Design

The vast majority of weir and dam structures that have been designed and constructed in New Zealand have been based only on physical properties of water which is the basis of engineering understanding and approach. To design for safe fish passage, both upstream and downstream requires a design approach that also includes an understanding of how to design for reduced risk of harm to fish and to maintain safe passage. This requires specialist engineering skills and knowledge; input from a suitably qualified and experienced freshwater ecologist on its own will not achieve that.

The design needs to consider not just the outlet structures such as the gates but also the downstream components. The design of these structures all impact on the risks associated with the mechanisms for harm to fish. It is often not possible to remove all risks but there are ways to reduce them.

Therefore, I believe the risks of harm to kōaro larvae at the site are significantly greater than what has been presented. Kōaro of other life stages also are at risk from the turbine, the various gates and associated downstream infrastructure and the weir when spilling; but are less likely to be moving downstream. In addition to barotrauma risks, travel through these structures and especially the downstream conditions of the flow hydraulics may have risks from physical strike and shear stress if the design is based solely on physical properties of water and does not include design parameters for fish protection.

7.0 Engineering Issues

7.1 Original Questions from Panel outlined in scope

a) Whether the intake structure is going to pass residual flow reliably

In response to this there are several considerations. Firstly as I have highlighted in regard to upstream fish passage at the intake structure the current proposed location of the residual flow structure is not ideal in regards to fish passage given kōaro will be attracted to the outlet from this structure and given its location between the hydro power intake and sluice gate; it is not a suitable location to direct fish to. It would seem better to have the residual flow located on the river left side of the sluice gate near the overflow weir, which is also where the current proposal for a fish pass is suggested. Or alternatively there needs to be downstream infrastructure to convey these flows to the other side of the structure.

I have also highlighted the potential risk of harm to fish and especially larvae with a very low outlet structure regarding barotrauma. The indication that this gate is likely to be mostly closed to maintain $3.5\text{m}^3/\text{s}$ increases risk from physical strike and shear energy given the very high velocities.

The other risks associated with that location may be that the intake (which will take up to $23\text{m}^3/\text{s}$) will attract large volumes of sediment and in addition to sand will include gravel, cobbles and larger rocks. Given the level of the intake and location this would seem to carry a significant risk around the deposition of coarser sediment which could impact on flow capacity and even lead to blockage.

In 2.2.5 of the Sediment Report it stated that large floods may, from time to time, deposit gravel that may block the intake. There does not appear to have been any significant work done to model or assess in any detail the risks associated with coarser sediment at the intake. There is a focus on design to manage sand.

It is proposed that the intake screen will have openings of 30–40mm. This will limit the size of material that will enter the intake but will still result in gravel and significant sized rocks through that screen as not all rock is spherical in shape. Larger rocks and debris will be deposited in front of that screen. From the sediment report it suggests cleaning gravel and rock in front of the intake will be relatively easy but likely cleaning out that material within the intake will be significantly more difficult.

So, the answer to this question is that the proposed residual flow structure in its current location would seem to have several concerns related to fish passage (upstream and downstream effects) and risk of effects from sediment deposition and or blockage. A location further to the river left and higher or different mechanism for releasing this flow would seem to reduce the risks associated with all these highlighted issues.

b) Whether the Intake structure is going to pass sediment reliably.

The response to (a) above has highlighted some of the potential concerns related to coarse sediment being deposited in front of the intake and within the intake. The system of the desander regarding velocities and storage of sand more than 0.3mm in diameter and the sluicing of it appears to be a reasonable system (for sand). There is no detailed hydraulic design information provided to be able to confirm how this will operate but in general terms it looks like it should work as I have estimated the velocity within the desander when clean will be in the order of 0.25 – 0.3m/s. Generally medium sand will deposit for velocities below approximately 0.5m/s. The sluicing of the desander will increase velocities that should remobilise sand but is likely limited as to what it will achieve with much coarser sediment.

The concern is coarser sediment and debris. Given the risks associated with these issues at this site I would expect to see detailed analysis of these issues as they could have very significant operational impacts. Given the most common and most significant problems at river intakes relate to sediment and debris management an intake proposed for an alpine West Coast River should have a very detailed assessment and work associated with suitable engineering structures to manage it. Although the sluice gate proposed is likely to be able to move coarse sediment close to the sluice opening there are no details presented of how far upstream the sluice would be effective in moving coarse sediment. With coarse sediment generally sluicing systems are very limited as to what they can achieve.

c) Whether the desander is likely to work as intended

Continuing from comments above the sand should also be remobilised with the desander flushing (again with no hydraulic design can only base that upon general principles related to the geometry). The concern is any coarser sediment that deposits between the intake and the start of the desander or even in the desander which will include gravel and rocks of various shapes that can move through a 30–40mm opening between screen bars.

d) The overall robustness of the analysis and conclusions, any gaps or areas where clarification or further information would assist, and the appropriateness of the conditions to address hydraulic engineering matters

A river intake is a very complex and challenging structure to design and even more difficult in a site such as is proposed for the Waitaha hydro power intake. The process for the design of an intake traditionally would focus on the hydrology of the river and the hydraulics, the physical properties of water to consider flows, velocities, water levels etc. It would then include a consideration of other factors such as sediment transport and debris. More modern approaches would also be expected to consider environmental, cultural, social and safety related issues and integrate all of these within the hydraulic design processes.

To begin with there is very little information on the hydraulic design basis for the various structures and the drawings are very limited in what they are showing and do not provide more details of how water is conveyed downstream from the structures and back to the river. The recent RFI response has included some more information on the hydraulics but is limited to a brief summary.

The challenge with this is that it is a very complex system and all the above often can have competing requirements. The process becomes an optimisation approach as often a change in one aspect to meet a certain need may have a detrimental impact on another aspect. Where these secondary considerations are brought in later in the design process and rather than an integrated design it becomes a process of retrofitting requirements into a design.

My impression of what is presented in this design is that it is following this approach and is indicating that the other needs/values such as environmental, cultural, social and safety will be included within the detailed design. The danger with this approach is that the design for the physical properties of water is generally given greater priority over other requirements and limits the ability to integrate these important values better within a design. This is often why many of the structures we have in our rivers have a negative impact on freshwater fish; why most fish passes do not work at dams and weirs; and why the movement of water downstream through the various parts of these structures have significant risk of harm to fish. The best chance of an effective design for fish passage will require consideration of harm to fish in the design of the structures and in all parts of the system where water is moving.

7.2 Hydraulic analysis and design of the river intake

As discussed, the design of the intake and associated infrastructure is extremely challenging and complex for this location. The management of debris and sediment and maintaining fish passage while also considering wider geomorphological effects at the highest energy location of a West Coast River requires detailed assessment to provide for a suitable concept. To have confidence in a design presented for consent and therefore to be able to consider effects requires detailed analysis and hydraulic modelling including assessment of sediment and debris combined with a consideration of geomorphological effects and design for upstream and downstream fish passage. The application has presented some of the information as a basis for that work but has not presented sufficiently detailed analysis and modelling of the structures proposed and how they will operate and the impacts from sediment, debris and variations in flow conditions. It also has not presented how suitable protection of upstream and downstream fish passage will be achieved by the intake structure. This detailed analysis I expect will show that residual effects will remain rather than currently what is presented which is that the effects will be fully resolved in detailed design. The extent of the residual effects that cannot be resolved can only be considered with a more detailed assessment.

8.0 Conclusions

The following are the key points regarding the issues I have raised within this review. I am not convinced that the proposed intake structure is the best and most suitable option for this location and purpose. This especially relates to issues of sediment and debris management or impacts on fish passage both upstream and downstream. I have concerns with the lack of integration within the concepts presented and question whether it will be able to do more than just control flows given the extreme challenges this location poses both from the physical environment and the importance of maintaining safe fish passage. The questions I listed earlier include whether this type of intake is the most appropriate to meet all the diverse needs of the intake. It is a traditional approach to construct a perpendicular weir across a river to form an intake, but history shows the many problems this type of design can result in.

For a number of the issues raised the Applicant has indicated will be addressed in detailed design. Some of the information I have presented questions whether these issues can be resolved in detailed design or whether there will be an effect that remains.

- The tailrace is a risk of being a significant barrier to upstream fish passage for up to 50% of the juvenile kōaro migrating upstream on the northern side of the river. It also creates an area that will attract various species of fish which is a dead-end for upstream fish passage and introduces risks of predation from trout and eels for other fish including kōaro. It is proposed to address this issue in detailed design, but no suggested solution has been presented, and the hydrology and hydraulics of the flows will make this a difficult effect to overcome.

- The significant reduction in flows between the intake and tailrace for over 70% of the time may risk introducing other fish species upstream of Morgan Gorge and the most likely risk will be the introduction of eel. Although longfin eel has the same threat classification as kōaro and are a taonga species in this river the introduction of eel upstream would be detrimental to kōaro with limited benefit to eel given they are excluded naturally from that habitat.
- The design of the intake weir has not presented any solution for upstream passage at this structure that gives any degree of comfort that it will not be a barrier to upstream fish passage for the kōaro. The majority of weir structures that have had fish passes included are not effective as the construction of a fish pass on its own is not enough to ensure effectiveness: there has to be a design that is integrated within the hydraulics of the structure that creates suitable attraction for the fish at the downstream part, is able to manage the flows within the pass for a variety of hydraulic conditions and ensure the upstream part is suitably placed to enable fish passage upstream away from the structure.
- There is no evidence presented that shows any development of means to convey water downstream with an approach to reduce or minimise risk of harm to fish. This includes flows at the Intake, hydro power systems, environmental flow, sluice flow and overflow at weir. Some of the design concepts presented and discussed follow practices that are known to combine different mechanisms of risk of harm to fish. The design basis for the hydraulics at these structures should include approaches that reduce the risk of harm to fish.
- There is no significant analysis of how coarse sediment will be managed as focus appears to be on the sand that will deposit in the desander. So, the coarser sediment that will deposit in front of the intake and within the intake has not been presented which appears to be a significant risk for this structure. This includes what the quantities, size and location of this material and how that will be managed or how the structure and operation will be affected as that occurs.
- There is no information on the issues of debris and how it will be managed (for this location the sediment does appear to be a much greater risk). A 30mm to 40mm screen opening will result in much of the debris in the flow into the intake to be trapped.
- There is little evidence of the important processes of integration of the design of the intake to include all the physical processes of water, sediment and debris combined with the important values and needs from environmental, cultural, social and safety to achieve the best outcomes for all these different values are achieved.

9.0 Limitation

This report has been prepared solely for the benefit of Waitaha Hydro Expert Consent Panel and the Environment Protection Authority as our client with respect to the brief. The reliance by other parties on the information or opinions contained in the report shall, without our prior review and agreement in writing, be at such parties' sole risk.

The analyses and recommendations contained in this report are based on our understanding and interpretation of the available information. The recommendations are therefore subject to the accuracy and completeness of the information available at the time of the review. Should any further information become available, the analyses and findings of this report should be reviewed accordingly.

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